Description: Learners model the fusion process that occurs in the Sun's core to produce light and heat. Using small basketballs with Velcro® representing protons, participants will try to get two balls to stick or fuse together while being blindfolded.

Background: The National Science Standards call for learners to understand that the Sun is the primary source of heat and light. Many elementary learners may think that the Sun is a giant ball of fire. In this activity, learners will gain an understanding of how the Sun produces energy by modeling the proton-proton fusion reaction that occurs in the Sun's core. Just as protons in the Sun's core are unable to fuse instantly, participants will find it very challenging to get the symbolic protons to fuse and may notice that the balls must collide at the right speed, at the right angle, and with enough energy for fusion to occur.

What is the significance of the learners trying to hit the "target" while blindfolded? Well, if we could see the Sun's core it would be black, since all the photonic energy produced from the proton-proton fusion is too great to be visible to the human eye. So, protons are colliding with other protons "in the dark." In the activity, learners model the first step in the fusion reaction that occurs in the Sun's core (the innermost zone). It has been calculated that it takes a given solar proton 14,000 million years to find a "hot partner" with which to fuse. Protons may travel for long periods without colliding with another proton in the Sun's core. They may also collide with one another many times without "fusing."

For instance, two exceedingly "hot" protons, that are hydrogen atoms without electrons, collide. This violent event results in the fusion of the two nuclei and the formation of a deuteron, a positron, and a neutrino. This event can be written conveniently in equation form, where superscripts attached to elemental symbols represent mass number:

$$^{1}H \quad + \quad ^{1}H \longrightarrow \; ^{2}D \quad + \quad ^{0}e^{+} \quad + \quad \nu_{c}$$

Two hot hydrogen atoms collide to produce a deuteron, positron and neutrino.

For more information about proton-proton fusion, read "Invisible Fire" from the module *Cosmic Chemistry: The Sun and Solar Wind:* http://genesismission.jpl.nasa.gov/educate/scimodule/SSWPrOptPDFs/2HowHotIsIt/InvisibleFire-ST-PO.pdf

National Science Standards[1]
3-5 Nature of Science
Understands the nature of scientific inquiry
Plans and conducts simple investigations

3-5 Earth and Space Sciences

Understands atmospheric processes and the water cycle

The Sun provides the light and heat necessary to maintain the temperature of the Earth

6-8 Earth and Space Sciences

Understands atmospheric processes and the water cycle

Knows that the Sun is the principle energy source for phenomena on the Earth's surface

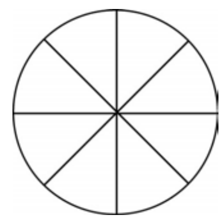
6-8 Physical Sciences

Understands the sources and properties of energy

Knows that the Sun acts as a major source of energy for changes on the Earth's surface

[1]Kendall, J.S. & Marzano, R.J. (2000). *Content Knowledge: A Compendium of Standards and Benchmarks for K-12 Education.* (3rd ed.). Alexandria, VA: Association for Supervision and Curriculum Development.

Materials (For the Class)



- Two plastic, inflatable mini-basketballs; one for the "target," one for the "bullet." (Those that are 11 cm in diameter are best.)
- Velcro® strips (2 cm wide)—enough to divide the surface of the balls into eight zones like illustration shown on the right
- Length of string to suspend the "target" ball
- One or two blindfolds
- Numbers on a piece of paper to determine the order the groups will go
- Write-On Sheet, "Proton Smasher" (one per student or group)

Leader Tip
If the model seems too challenging for the group of learners, additional Velcro® strips may be added.

Advanced Preparation:

- Glue to attach Velcro® strips to the balls. (SuperGlue® is best.)
- Use a length of string to suspend the "target" ball from the ceiling so that it hangs at about shoulder height of your learners.
- Using masking tape, mark off a "firing" line no closer than 1 meter from the suspended ball. The distance from the ball will be determined by the age of your participants. It should be far enough from the target to make hitting the target a challenge, yet close enough to make hitting the target possible.

Leader Tip
For larger groups of participants, set up multiple stations. This will minimize the amount of time spent waiting for a turn.

Procedure:

1. Ask learners where the light and heat we have on the Earth comes from. (Some students may say the Sun, others might think from deep inside the Earth.) Introduce the activity by explaining that they will demonstrate what happens in the middle of the Sun to produce the heat and light energy and that the Earth receives only a small part of this heat and light energy.

2. Divide the class into teams of no more than four learners. Have each team elect a team captain and "recorder." Have each team captain draw numbers to determine the order.

3. Hand a copy of the Write-On Sheet, "Proton Smasher," to each participant. Explain that each person will take turns trying to get the "bullet" ball to stick to the "target" ball while blindfolded. Each participant will have a total of 5 throws or 5 chances to get the balls to stick.

4. The recorder should record the number of "sticks," "hits," and "misses" for each participant on the Write-On Sheet.

5. Learners should switch tasks and repeat the process until all have had a turn throwing the "bullet" ball at the "target."

6. Ask learners to describe what happened in the activity they just completed. (Most learners will describe that few, if any participants, were able to make the ball stick. Some may have been able to make it hit, while most missed.)

7. Explain to the learners that this activity modeled fusion or the beginning of the process in the middle of the Sun that releases energy in the form of heat and light.

> **Leader Tip**
> As a variation, participants could try initially to hit a swinging "target" ball without a blindfold. Then, they could attempt to hit a stationary "target" ball while blindfolded.

8. Explain that in this model the "bullet" ball and "target" ball represent very tiny particles in the core of the Sun called protons. These protons move about at high rates of speed in the middle of the Sun. For one particular proton, it may take 14,000 million years to "stick" with another! Yet they may collide and not fuse, much like the balls in this activity would hit without sticking. Explain that they were blindfolded because there is no visible light (or radiation) in the center of the Sun, so the protons can't "see" where the other protons are.

9. Ask older learners to answer questions 7-10 on the Write-On Sheet. Use the activity to help them describe the first step of nuclear fusion. Ask them to think about what made this a good model and what made this a poor model. Ask them to think about ways to improve the model.

10. As a closing discussion for the activity, encourage participants to begin to reflect on the number of protons and the amount of activity that occurs in the Sun's core. The following suggestion offers one way to initiate such a discussion:

    How many of you would agree that the Sun produces a tremendous amount of energy? Think about how the Sun's energy is used on Earth. How do we depend on the Sun's energy? (Responses will vary from growing plants and vegetables to using solar power to heat homes.) Remember at the beginning of the activity, I mentioned that Earth receives only a small portion of the Sun's energy. Through the activity, you learned that tiny protons in the Sun have to fuse together to begin the process of producing heat and light energy. You also learned that this proton-proton fusion doesn't happen easily; it can take 14,000 million years for a proton to stick with another. So if the fusion process is that challenging, how can the Sun create so much energy – enough energy to support all living things on Earth? What does this tell us about the number of protons in the Sun's core? (Participants should begin to understand that there must be many protons present in the Sun's core.)

This activity was adapted for Community Quest from an activity in the Genesis education module *Cosmic Chemistry: The Sun and Solar Wind* found at:
http://www.genesismission.org/educate/scimodule/SunandSolar/index.html

Resource for Extension and Enrichment Activities

http://www.eyeonthesky.org/lessonplans/XXsun_lessonparts.html
Eye on the Sky features a learning activity and accompanying teacher guide entitled "Layers of the Sun" to illustrate and explain the movement of energy from the Sun's core to the outer regions.

http://www.genesismission.org/product/genesis_kids/ropingrainbows/ropingrainbows.html
Tap into the Sun's energy to make some solar treats. This site includes recipes to make Cosmic Cookies, Sun Tea, and to instructions to create your own solar hot dog cooker.